3.0 FLUID SELECTION

Choosing the right metalworking fluid for your operation can be confusing and time consuming. To select a fluid for your application, advantages and disadvantages of metalworking fluid products should be compared through review of product literature, supplier information, and usage history. Product performance information shared by other machine shops is another means of narrowing choices. Ultimately, the best indicator of fluid performance is through actual use.

In addition to the fluid properties discussed in Section 2, the following factors should be considered when selecting a fluid [1,2,8,9]:

- ✔ Cost and life expectancy
- ✔ Fluid compatibility with work materials and machine components
- ✔ Speed, feed and depth of the cutting operation
- ✔ Type, hardness and microstructure of the metal being machined
- ✔ Ease of fluid maintenance and quality control
- ✔ Ability to separate fluid from the work and cuttings
- ✔ The product's applicable temperature operating range
- ✔ Optimal concentration and pH ranges
- ✔ Storage practices
- ✔ Ease of fluid recycling or disposal

One thing must be remembered when choosing fluids – you generally get what you pay for. Don't choose a fluid just on its initial cost but on the cost per gallon divided by its life expectancy. Although purchase of a premium product is initially more expensive, the long-term cost of the fluid will likely be lower than products of inferior quality because of its superior fluid life.

During fluid selection, the benefits of a fluid's versatility should be weighed against its performance in each metalworking application [1,10]. Because of significant improvements in fluid formulations, today's fluids are capable of handling a wide variety of machining applications [2]. Machine shops that once required several types of fluids may now find that one or two fluid types meet their needs. Consolidating the number of fluids used in the shop simplifies fluid management.

The most common metalworking fluids used today belong to one of two categories based on their oil content [2,8]:

Oil-Based Fluids - including straight oils, soluble oils and ag-based oils
Chemical Fluids - including synthetics and semisynthetics

Fluids vary in suitability for metalworking operations. For example, petroleum-based cutting oils are frequently used for drilling and tapping operations due to their excellent lubricity while water-miscible fluids provide the cooling properties required for most turning and grinding operations.

The following provides a description of the advantages, disadvantages and applications of each metalworking fluid category.

3.1 OIL-BASED CUTTING FLUIDS

3.11 STRAIGHT OILS (100% petroleum oil)

Straight oils, so called because they do not contain water, are basically petroleum, mineral, or ag-based oils. They may have additives designed to improve specific properties [1,3]. Generally additives are not required for the easiest tasks such as light-duty machining of ferrous and nonferrous metals [8,11]. For more severe applications, straight oils may contain wetting agents (typically up to 20% fatty oils) and extreme pressure (EP) additives such as sulfur, chlorine, or phosphorus compounds. These additives improve the oil's wettability; that is, the ability of the oil to coat the cutting tool, workpiece and metal fines [12]. They also enhance lubrication, improve the oil's ability to handle large amounts of metal fines, and help guard against microscopic welding in heavy duty machining. For extreme conditions, additives (primarily with chlorine and sulfurized fatty oils) may exceed 20%. These additives strongly enhance the antiwelding properties of the product [11].

ADVANTAGES. The major advantage of straight oils is the excellent lubricity or "cushioning" effect they provide between the workpiece and cutting tool [3]. This is particularly useful for low speed, low clearance operations requiring high quality surface finishes [8,11]. Although their cost is high, they provide the longest tool life for a number of applications. Highly compounded straight oils are still preferred for severe cutting operations such as crush grinding, severe broaching and tapping, deep-hole drilling, and for the more difficult-to-cut metals such as certain stainless steels and superalloys. They are also the fluid of choice for most honing operations due to their high lubricating qualities [12].

Straight oils offer good rust protection, extended sump life, easy maintenance, and are less likely to cause problems if misused. They also resist rancidity, since bacteria cannot thrive unless water contaminates the oil [8].

DISADVANTAGES. Disadvantages of straight oils include poor heat dissipating properties and increased fire risk [8,11]. They may also create a mist or smoke that results in an unsafe work environment for the machine operator, particularly when machines have inadequate shielding or when shops have poor ventilation systems. Straight oils are usually limited to low temperature, low-speed operations [1]. The oily film left on the workpiece makes cleaning more difficult, often requiring the use of cleaning solvents.

Straight oil products of different viscosities are available for each duty class. Viscosity can be thought of as a lubricant factor--the higher the oil's viscosity, the greater its lubricity. Highly viscous fluids tend to cling to the workpiece and tool. This causes increased cutting fluid loss by dragout and necessitates lengthier, more costly cleanup procedures. It can be more efficient to choose a low-viscosity oil that has been compounded to provide the same lubricity as a highly viscous one.

3.12 SOLUBLE OILS (60-90% petroleum oil)

Soluble oils (also referred to as emulsions, emulsifiable oils or water-soluble oils) are generally comprised of 60-90 percent petroleum or mineral oil, emulsifiers and other additives [1,8,13]. A concentrate is mixed with water to form the metalworking fluid. When mixed, emulsifiers (a soap-like material) cause the oil to disperse in water forming a stable "oil-in-water" emulsion [2,12]. They also cause the oils to cling to the workpiece during machining. Emulsifier particles refract light, giving the fluid a milky, opaque appearance.

ADVANTAGES. Soluble oils offer improved cooling capabilities and good lubrication due to the blending of oil and water [12]. They also tend to leave a protective oil film on moving components of machine tools and resist emulsification of greases and slideway oils [2].

Soluble oils are a general purpose product suitable for light and medium duty operations involving a variety of ferrous and nonferrous applications. Although they do not match the lubricity offered by straight oils, wetting agents and EP additives (such as chlorine, phosphorus or sulfur compounds) can extend their machining application range to include heavy-duty operations. Most cutting operations handled by straight oils (such as broaching, trepanning, and tapping) may be accomplished using heavy-duty soluble oils.

Soy-based cutting fluid

The University of Northern Iowa's (UNI) Ag-Based Industrial Lubricants (ABIL) Research Program, established in 1991, is a nationally recognized technical service group offering guidance and expertise on biobased (soybean) industrial lubricants. It is one of nine outreach programs sponsored by UNI's Business and Community Services (BCS) group. Research conducted at ABIL provides our nation's agricultural community with an expanded market for soy products. UNI-ABIL is a not-for-profit organization that receives support from federal, state, and private organizations.

The use of soybean oil for metalworking began as an alternative to conventional products. The performance observed shows a significant breakthrough in the use of soybean oil in metalworking applications. Soybean oil, like many other vegetable oils, presents superior lubricity in many industrial applications. Metalworking applications present an extremely harsh environment for lubricating oils. Exposure to air, heat, moisture, light and metal shavings (which act as catalysts in the breakdown of the lubricant) creates special problems when using metalworking lubricants.

UNI-ABIL researchers have been using a genetically altered strain of soybeans that produces soybean oil rich in tri-olean. This high molecular weight oil has a flash point of about 600°F (320°C) as compared to 420°F (216°C) for petroleum-based oils. Due to the polar nature of the oil, it bonds well with metal surfaces and therefore is very effective as a friction reducer. The oil has very high film strength. This helps prevent boundary lubrication and therefore helps reduce heat and tool wear. In addition, the low volatility of the oil prevents evaporation at the tip of the tool thus further preventing tool wear.

Metalworking fluids and machine lubricants developed at UNI-ABIL offer a number of ways to reduce operating costs. Most companies are interested in biodegradable products, especially those produced from renewable resources that help agribusiness. Soy based cutting oils produce less smoke and less mist, which are both important health concerns. Soy oil contains no chlorine or sulfur which are common to petroleum based cutting oils. Because of superior lubricity of soy-based oils, tool costs are greatly diminished and production gains are achieved because of increased feed rates and improvement in part finish. Grinding applications have actually shown a 50% reduction in wheel costs with the introduction of soy-based lubricants. In the brief period since the initial development of soy-based cutting fluids, more than 50 industries have made the change to the more environmentally friendly material. UNI-ABIL has found that most industries want to be pro-active where environmental issues are involved.

The acceptance by industry of the cutting oil developed by researchers at UNI-ABIL has exceeded expectations. Business is driven by profit and is therefore reluctant to change current practice or methods unless it can be demonstrated there is an advantage to change. Some

issues to be considered when changing metal cutting coolants include cost, productivity, equipment compatibility, operator acceptance and health issues. In spite of all these issues, UNI-ABIL has been given the opportunity to test at more than half of the companies that have been contacted.

Clearline Cutlery, located in Traer, Iowa, is a company that recently converted to SoyEasy™ Cool in its surface grinding operations. Clearline Cutlery uses grinding wheels to manufacture and recondition blades for the food industry. The number of grinding wheels used per year dropped from 162 using petroleum-based lubricants to 60 grinding wheels with the soy-based cutting oil developed at UNI-ABIL. This change resulted in a cost savings of over $11,000 in its first year of operation. Similar savings were noted at Hawkeye Tool and Die. Hawkeye was using petroleum-based cutting coolant in a power band saw to cut 12-inch diameter stainless steel bar stock. SoyEasy™ Cool with its superior lubricity and cooling ability was able to prevent the blade from wandering. This improvement helped reduce the safety stock by 0.38 inches per piece. This resulted in a net savings of over $4,000 per 50-piece run of this stainless steel part.

Health concerns are a major issue in any tooling operation. Smoke caused by heat from the tooling operation and mist generated by the cutting tools or grinding wheels are major health concerns. UNI-ABIL, Waterloo John Deere Tractor Works, and Castrol Industrial Americas are currently funding ($28,000) a toxicity study of bio-based machining fluids at the Environmental Health Sciences Research Center at the University of Iowa, Oakdale Campus. Comparisons are being made between neat and used metalworking fluids. The test subjects for this study are mice. The scope of work centers on respiratory and vision difficulties that may result from exposure to mists of the various fluids. Preliminary results indicate there is no pathological inflammation occurring in the lungs or eyes of mice subjected to acute concentrations of either neat or used petroleum-based or soy-based cutting fluids. In the microbial assessment of soy and petroleum-based cutting fluids, all samples showed fungal growth. Bacterial breakdown of petroleum and soy-based cutting fluids continues to be a problem, however preliminary results being carried on at UNI-ABIL indicate breakdown of soy-based oil can be abated with suitable additives.

The use of soybean oil for metalworking fluids started as an alternative to conventional products. The performance observed shows a breakthrough in the metal working area. Soy-based oils currently match the price and performance of petroleum or semi-synthetic oils. UNI-ABIL has licensed several of the metalworking fluids for commercialization. The future for soy-based lubricants is very encouraging. UNI-ABIL is positioned to be a leader in this new technology.

For more information regarding the ABIL Research Program please visit our website at www.uni.edu/abil. For additional information please send questions or comments to Dr. Lou Honary, Director, to email address abil@uni.edu. If you would like additional information regarding products developed by ABIL Research Program for commercial sale please contact ELM Inc., at (319) 352-5300, or visit their website, www.elmusa.com for a full product listing.

Soy-based cutting fluid

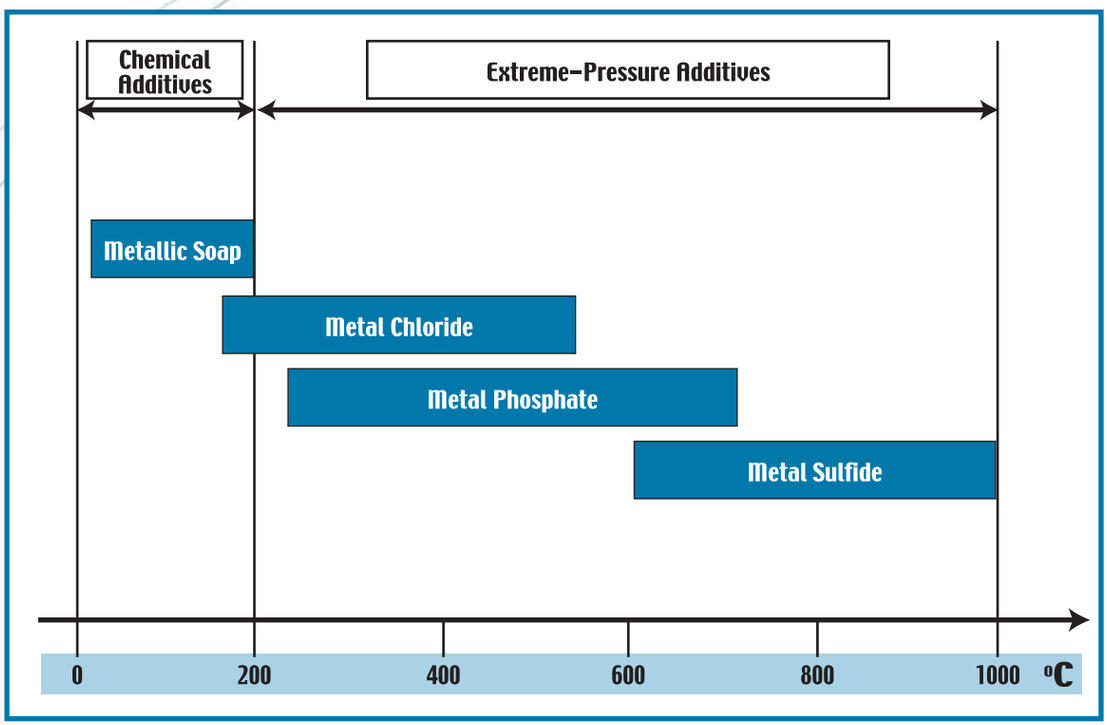

Figure 3-1 Temperature efficiency range of chemical and EP lubricant additives (modified from K. Bienkowski, 1993).

DISADVANTAGES. The presence of water makes soluble oils more susceptible to rust control problems, bacterial growth and rancidity, tramp oil contamination, and evaporation losses. Soluble oils are usually formulated with additives to provide additional corrosion protection and resistance to microbial degradation. Maintenance costs to retain the desired characteristics of soluble oil are relatively high. Other disadvantages of soluble oils include the following:

When mixed with hard water, soluble oils tend to form precipitates on parts, machines and filters [8,11]; Due to their high oil content, they may be the most difficult of the water-miscible fluids to clean from the workpiece. As a result of these disadvantages, soluble oils have been replaced in most operations with chemical cutting fluids.

Misting of soluble oils may produce a dirty and unsafe work environment, through slippery surfaces and inhalation hazards.

3.2 CHEMICAL CUTTING FLUIDS

Chemical cutting fluids, called synthetic or semisynthetic fluids, have been widely accepted since they were first introduced in about 1945. They are stable, preformed emulsions which contain very little oil and mix easily with water. Chemical cutting fluids rely on chemical agents for lubrication and friction reduction [8].

These additives also improve wettability. At temperatures above approximately 390°F (200°C), these additives become ineffective and EP lubricant additives (chlorine, phosphorus and sulfur compounds) are utilized.

These compounds react with freshly-machined metal to form chemical layers which act as a solid lubricant and guard against welding during heavy-duty machining operations. Fluids containing EP lubricants significantly reduce the heat generated during cutting and grinding operations. Figure 3-2 illustrates the temperature efficiency range of chemical and EP lubricant additives [8].

3.21 SYNTHETICS (0% petroleum oil)

Synthetic fluids contain no petroleum or mineral oil [2,11]. They were introduced in the late 1950's and generally consist of chemical lubricants and rust inhibitors dissolved in water. Like soluble oils, synthetics are provided as a concentrate which is mixed with water to form the metalworking fluid. These fluids are designed for high cooling capacity, lubricity, corrosion prevention, and easy maintenance. Due to their higher cooling capacity, synthetics tend to be preferred for high-heat, high-velocity turning operations such as surface grinding. They are also desirable when clarity or low foam characteristics are required. Heavy-duty synthetics, introduced during the last few years, are now capable of handling most machining operations.

Synthetic fluids can be further classified as simple, complex or emulsifiable synthetics based on their composition [8,11]. Simple synthetic concentrates (also referred to as true solutions) are primarily used for light duty grinding operations [2]. Complex synthetics contain synthetic lubricants and may be used for moderate to heavy duty machining operations. Machining may also be performed at higher speeds and feeds when using complex synthetics. Both simple and complex synthetics form transparent solutions when mixed in a coolant sump, allowing machine operators to see the workpiece.

Emulsifiable synthetics contain additional compounds to create lubrication properties similar to soluble oils, allowing these fluids to double as a lubricant and coolant during heavy-duty machining applications. Due to their wettability, good cooling and lubricity, emulsifiable synthetics are capable of handling heavy-duty grinding and cutting operations on tough, difficult-to-machine and high temperature alloys [2]. The appearance of emulsifiable synthetic fluids ranges from translucent to opaque.

Chemical agents found in most synthetic fluids include:

- ✔ Amines and nitrites for rust prevention
- ✔ Nitrates for nitrite stabilization
- ✔ Phosphates and borates for water softening
- ✔ Soaps and wetting agents for lubrication
- ✔ Phosphorus, chlorine, and sulfur compounds for chemical lubrication
- ✔ Glycols to act as blending agents
- ✔ Biocides to control bacterial growth

ADVANTAGES. Synthetic fluids have the following qualities which contribute to superior service life [8,23]:

- ✔ Excellent microbial control and resistance to rancidity for long periods of time;
- ✔ Nonflammable, nonsmoking and relatively nontoxic;
- ✔ Good corrosion control;
- ✔ Superior cooling qualities;
- ✔ Greater stability when mixed with hard water;
- ✔ Reduced misting problems; and
- ✔ Reduced foaming problems.

Synthetics are easily separated from the workpiece and chips, allowing for easy cleaning and handling of these materials. In addition, since the amount of fluid clinging to the workpiece and chips is reduced, less makeup fluid is needed to replace coolant lost to drag-out.

Good settling properties allow fine particulates to readily drop out of suspension, preventing them from recirculating and clogging the machine-cooling system. Overall, synthetics are easier to maintain due to their cleanliness, they offer long service life if properly maintained and can be used for a variety of machining operations.

DISADVANTAGES. Although synthetics are less susceptible to problems associated with oil-based fluids, moderate to high agitation conditions may still cause them to foam or generate fine mists [1]. A number of health and safety concerns, such as misting and dermatitis, also exist with the use of synthetics in the shop [8]. Ingredients added to enhance the lubricity and wettability of emulsifiable synthetics may increase the tendency of these fluids to emulsify tramp oil, foam and leave semi-crystalline to gummy residues on machine systems (particularly when mixed with hard water) [2].

Synthetic fluids are easily contaminated by other machine fluids such as lubricating oils and need to be monitored and maintained to be used effectively [1,12].

3.22 SEMISYNTHETICS (2–30% petroleum oil)

As the name implies, semisynthetics (also referred to as semi-chemical fluids) are essentially a hybrid of soluble oils and synthetics. They contain small dispersions of mineral oil, typically 2 to 30 percent, in a water-dilutable concentrate [1,8,14]. The remaining portion of a semi-synthetic concentrate consists mainly of emulsifiers and water. Wetting agents, corrosion inhibitors and biocide additives are also present. Semisynthetics are often referred to as chemical emulsions or preformed chemical emulsions since the concentrate already contains water and the emulsification of oil and water occurs during its production.

The high emulsifier content of semisynthetics tends to keep suspended oil globules small in size, decreasing the amount of light refracted by the fluid. Semisynthetics are normally translucent but can vary from almost transparent (having only a slight haze) to opaque [8,11]. Most semisynthetics are also heat sensitive. Oil molecules in semisynthetics tend to gather around the cutting tool and provide more lubricity. As the solution cools, the molecules redisperse.

ADVANTAGES. Like synthetics, semisynthetics are suitable for use in a wide range of machining applications and are substantially easier to maintain than soluble oils. They provide good lubricity for moderate to heavy duty applications. They also have better cooling and wetting properties than soluble oils, allowing users to cut at higher speeds and faster feed rates [8]. Their viscosity is also less than that of a soluble oil, providing better settling and cleaning properties. Semisynthetics provide better control over rancidity and bacterial growth, generate less smoke and oil mist (because they contain less oil than straight or soluble oils), have greater longevity, and good corrosion protection.

DISADVANTAGES. Water hardness affects the stability of semisynthetics and may result in the formation of hard water deposits. Semisynthetics also foam easily because of their cleaning additives and generally offer less lubrication than soluble oils.

WHY IT'S SOYEASY TO SWITCH

To SoyEasy™ Biotechbased Metalworking Fluids

CHARACTERISTIC	BENEFIT
BIOBASED	• Comes from US grown soybeans - a renewable U.S. resource. • Aids our farm and U.S. economy. • Reduces dependence on foreign oil.
LOWER OPERATING COSTS	• Increased productivity, reduced coolant usage and less tramp oil to dispose of.
SUPERIOR LUBRICITY	• OptiBase™ 3000 high oleic soybean oil has superior lubricity. Better adhesion to metal surfaces
LONGER TOOL LIFE	• Extends tool life by up to 50%.
FEED RATES & SPEEDS	• Increases feed rates and production conventional fluids.
SURFACE FINISH	• Improves surface finishes and centricity.
SAVES ENERGY	• Reduces friction, lowers power consumption and saves energy.
PRICE & VALUE	• Priced similar to conventional metalworking fluids. • Better end-use cost and value to improve your bottom line.
BIODEGRADABLE	• Readily biodegradable. Safer for the environment. • Easier to dispose.
ISO 14000 BENEFITS	• Mostly natural ingredients. Less hazardous in the workplace. Helps comply with ISO 14000 - Environmental Management \ Standards.
COMPATIBILITY	• SoyEasy Cut (Straight cutting oils) are completely compatible with conventional petroleum fluids.

CHARACTERISTIC	BENEFIT
MULTIPLE USES	• The SoyEasy Metalworking Fluid line includes products for: cutting, grinding, hobbing, forming, drawing, tapping, reaming. It may also be used as a way lube and hydraulic oil.
SAFETY BENEFITS	• Higher flash and fire points than conventional fluids. • Produces less mist and smoke in the workplace. • No Chlorine or Sulfur.

ELM Biotech based

Soy fluid in screw machine

3.0

CUTTING FLUID TYPES: Advantages vs. Disadvantages

Straight Oils

ADVANTAGES - Excellent lubricity; good rust protection; good sump life; easy maintenance; rancid resistant

DISADVANTAGES - Poor heat dissipation; increased risk of fire, smoking and misting; oily film on workpiece; limited to low-speed, severe cutting operations

Soluble Oils

ADVANTAGES- Good lubrication; improved cooling capabilities; good rust protection; general purpose product for light to heavy duty operations

DISADVANTAGES - More susceptible to rust problems, bacterial growth, tramp oil contamination and evaporation losses; increased maintenance costs; may form precipitates on machine; misting; oily film on workpiece

Synthetics

ADVANTAGES - Excellent microbial control and resistance to rancidity; relatively nontoxic; transparent; nonflammable/nonsmoking; good corrosion control; superior cooling qualities; reduced misting/foaming; easily separated from workpiece/chips; good settling/cleaning properties; easy maintenance; long service life; used for a wide range of machining applications

DISADVANTAGES - Reduced lubrication; may cause misting, foaming and dermatitis; may emulsify tramp oil; may form residues; easily contaminated by other machine fluids

Semisynthetics

ADVANTAGES - Good microbial control and resistance to rancidity; relatively nontoxic; nonflammable/nonsmoking; good corrosion control; good cooling and lubrication; reduced misting/foaming; easily separated from workpiece/chips; good settling/cleaning properties; easy maintenance; long service life; used for a wide range of machining applications

DISADVANTAGES - Water hardness affects stability; may cause misting, foaming and dermatitis; may emulsify tramp oil; may form residues; easily contaminated by other machine fluids